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Claims

[c1] A chatter resistant shuttle valve to direct fluid flow from at least two sources of pressurized fluid to a downstream apparatus, the shuttle valve comprising:
a body engaging a pair of removable opposing coaxial adapters, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid and the body having a transverse outlet in fluid communication with the downstream apparatus;
a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the body;
a first skirt extending from the first adapter and surrounding the first metal valve seat and a second skirt extending from the second adapter and surrounding the second metal valve seat;
an elongate shuttle coaxial with the inlets slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to fluid flow from the sources of pressurized fluid;

the shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and a second opposing sealing surface to engage the second valve seat, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a band formed on an outside diameter, the band being sized to alternately slip inside the first skirt and the second skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the skirts;

the first and second tubular end portions of the shuttle sized to alternatively slip inside a first receptacle in the first adapter and a second receptacle in the second adapter with a minimal clearance between an outside diameter of the tubular end portions and an inside diameter of the receptacles;

the collar, the first skirt, the first valve seat and the first tubular end portion defining a first dampening chamber that receives fluid as the shuttle moves away from the first adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the first tubular end portion and the inside diameter of the first receptacle restricting the flow of fluid into the first

dampening chamber from the inlet; and
the collar, the second skirt; the second valve seat and the second tubular end portion defining a second dampening chamber that receives fluid as the shuttle moves away from the second adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the second tubular end portion and the inside diameter of the second receptacle restricting the flow of the fluid into the second dampening chamber from the inlet whereby the shuttle is less susceptible to disruption from momentary pressure changes from the sources of pressurized fluid.

[c2] The apparatus of claim 1 wherein the shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c3] The apparatus of claim 1 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c4] The apparatus of claim 1 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c5] The apparatus of claim 1 wherein the shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 second or shorter.

[c6] The apparatus of claim 1 wherein the minimal gap and the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c7] The apparatus of claim 1 wherein the ratio of the minimal gap to the diameter of the central collar of the elongate shuttle is about 0.05% to about 0.2%.

[c8] A retrofit kit for an existing shuttle valve to convert the valve to a chatter resistant design, the existing shuttle valve directing fluid flow from two or more sources of pressurized fluid to a downstream apparatus, the existing shuttle valve having a body with two opposing adapter ports and a transverse outlet in fluid communi-

cation with the downstream apparatus, the retrofit kit comprising:

a) a pair of removable opposing coaxial adapters each engaging the adapter ports in the valve body, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid;

a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the body;

a first skirt extending from the first adapter and surrounding the first metal valve seat and a second skirt extending from the second adapter and surrounding the second metal valve seat;

b) an elongate shuttle coaxial with the inlets and slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to differential fluid flow from the sources of pressurized fluid;

the shuttle including a central collar with opposing metal sealing surfaces to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a circular band formed on an

outside diameter, the circular band being sized to alternately slip inside the first skirt and the second skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the skirts;

the first tubular end portion being sized to slip inside a bore in the first adapter with a minimal clearance between the outside diameter of the first end portion and the inside diameter of the bore of the first adapter;

the second tubular end portion being sized to slip inside a bore in the second adapter with a minimal space between the outside diameter of the second end portion and the inside diameter of the bore of the second adapter;

the central collar, the first skirt, the first valve seat, and the first tubular end portion defining a first dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and the second inlet and retards movement of the shuttle from a closed position at the first inlet; and

the central collar, the second skirt, the second valve seat, and the second tubular end portion defining a second dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and the first inlet and retards movement of the shuttle from a closed position at the second inlet.

[c9] The apparatus of claim 8 wherein fluid flows a) from the outlet and the second inlet into the first dampening chamber through an annular area between the first skirt and the shuttle central collar and fluid flows b) from the first inlet into the first dampening chamber through an annular area between the first tubular end portion of the shuttle and the bore of the first adapter.

[c10] The apparatus of claim 8 wherein the shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c11] The apparatus of claim 8 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c12] The apparatus of claim 8 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c13] The apparatus of claim 8 wherein the shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 second or shorter.

[c14] The apparatus of claim 8 wherein the minimal gap and the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c15] The apparatus of claim 8 wherein the ratio of the minimal gap to the diameter of the central collar of the elongate shuttle is about 0.05% to about 0.2%.

[c16] A chatter resistant shuttle valve installed subsea at a depth of at least 5,000 feet
a body engaging a pair of removable opposing coaxial adapters, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid and the body having a transverse outlet in fluid communication with the downstream apparatus;
a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the body;

a first skirt extending from the first adapter and surrounding the first metal valve seat and a second skirt extending from the second adapter and surrounding the second metal valve seat;

an elongate shuttle coaxial with the inlets slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to fluid flow from the sources of pressurized fluid;

the shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and a second opposing sealing surface to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a band formed on an outside diameter, the band being sized to alternately slip inside the first skirt and the second skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the skirts;

the first and second tubular end portions of the shuttle sized to alternatively slip inside a first receptacle in the first adapter and a second receptacle in the second adapter with a minimal clearance between an outside diameter of the tubular end portions and an inside diame-

ter of the receptacles;

the collar, the first skirt, the first valve seat and the first tubular end portion defining a first dampening chamber that receives fluid as the shuttle moves away from the first adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the first tubular end portion and the inside diameter of the first receptacle restricting the flow of fluid into the first dampening chamber from the inlet;

the collar, the second skirt; the second valve seat and the second tubular end portion defining a second dampening chamber that receives fluid as the shuttle moves away from the second adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the second tubular end portion and the inside diameter of the second receptacle restricting the flow of the fluid into the second dampening chamber from the inlet whereby the shuttle is less susceptible to disruption from momentary pressure changes from the sources of pressurized fluid; and

whereby a shuttle valve with a 1 inch nominal inlet diameter creates a dampening force in excess of 2,000 psi on the shuttle.

[c17] A chatter resistant shuttle valve installed subsea at a depth of at least 10,000 feet;
a body engaging a pair of removable opposing coaxial adapters, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid and the body having a transverse outlet in fluid communication with the downstream apparatus;
a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the body;
a first skirt extending from the first adapter and surrounding the first metal valve seat and a second skirt extending from the second adapter and surrounding the second metal valve seat;
an elongate shuttle coaxial with the inlets slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to fluid flow from the sources of pressurized fluid;
the shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and a second opposing sealing surface to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plu-

rality of perforations through the tubular end portion to the bore;

the central collar having a band formed on an outside diameter, the band being sized to alternately slip inside the first skirt and the second skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the skirts;

the first and second tubular end portions of the shuttle sized to alternatively slip inside a first receptacle in the first adapter and a second receptacle in the second adapter with a minimal clearance between an outside diameter of the tubular end portions and an inside diameter of the receptacles;

the collar, the first skirt, the first valve seat and the first tubular end portion defining a first dampening chamber that receives fluid as the shuttle moves away from the first adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the first tubular end portion and the inside diameter of the first receptacle restricting the flow of fluid into the first dampening chamber from the inlet;

the collar, the second skirt; the second valve seat and the second tubular end portion defining a second dampening chamber that receives fluid as the shuttle moves away from the second adapter, the minimal gap restrict-

ing the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the second tubular end portion and the inside diameter of the second receptacle restricting the flow of the fluid into the second dampening chamber from the inlet whereby the shuttle is less susceptible to disruption from momentary pressure changes from the sources of pressurized fluid; and
whereby a shuttle valve with a nominal 1 inch inlet diameter creates a dampening force in excess of 4,000 psi on the shuttle.

[c18] A method of converting an existing shuttle valve to a chatter resistant design using a retrofit kit, the existing shuttle valve having a shuttle to direct fluid flow from two or more sources of pressurized fluid to a downstream apparatus, the existing shuttle valve having a body with two opposing removable adapters each engaging opposing adapter ports and the body having a transverse outlet in fluid communication with the downstream apparatus, the method comprising:
a) removing the existing adapters and the existing shuttle from the valve;
b) installing a first coaxial adapter in one of the adapter ports in the valve body, the first adapter defining a first inlet in fluid communication with a source of pressurized

fluid, the first adapter having a first metal valve seat surrounding the first inlet, a first skirt extending from the first adapter and surrounding the first metal valve seat;
c) installing an elongate shuttle coaxial with the first inlet;
the shuttle including a central collar with a first sealing surface and a second opposing sealing surfaces, the shuttle further including opposing first and second tubular end portions;
the central collar having a circular band formed on an outside diameter, the circular band being sized to slip inside the first skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the first skirt;
the first tubular end portion of the shuttle sized to slip inside a first bore in the first adapter with a minimal clearance between an outside diameter of the tubular end portion and an inside diameter of the bore;
the central collar, the first skirt, the first valve seat, the first tubular end portion defining a first dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and retards movement of the shuttle from a closed position at the first inlet;
d) installing a second adapter in the second adapter port in the valve body, the second adapter defining a second inlet in fluid communication with a source of pressurized

fluid, the second adapter having second metal valve seat surrounding the second inlet and a second skirt extending from the second adapter and surrounding the second metal valve seat;

the flat band formed on the collar being sized to slip inside the second skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the second skirt;

the second tubular end portion of the shuttle sized to slip inside a second bore in the second adapter with a minimal clearance between an outside diameter of the second tubular end portion and an inside diameter of the second bore; and

the central collar, the second skirt, the second valve seat, and the second tubular end portion defining a second dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and the first inlet and retards movement of the shuttle from a closed position at the second inlet.

[c19] A stacked chatter resistant shuttle valve to direct fluid flow from at least three sources of pressurized fluid to a downstream apparatus, the body shuttle valve comprising:

a body having a first supply port and a plurality of adapters defining subsequent supply ports and a func-

tion port, each supply port in fluid communication with one source of pressurized fluid, and the function port in fluid communication with the downstream apparatus;
a zigzag shaped fluid passageway in the body connecting the supply ports and the function port allowing fluid to move from the sources of pressurized fluid, through the supply ports, through the fluid passageway, through the function port to the downstream apparatus;
each adapter having a first metal valve seat surrounding the supply port and an opposing coaxial metal valve seat surrounding a section of the passageway;
a skirt extending from each adapter and surrounding each metal valve seat;
each of the subsequent supply ports having a shuttle coaxial with the metal valve seats, slidably moving from sealing engagement with the first valve seat to sealing engagement with the opposing valve seat in response to fluid flow from the sources of pressurized fluid
each shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and the opposing valve seat, each shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;
each central collar having a band formed on an outside diameter, the band being sized to slip inside the skirt

with a minimal gap between the outside diameter of each collar and an inside diameter of each skirt;
the first and second tubular end portions of each shuttle sized to alternatively slip inside a first receptacle in each adapter and a second receptacle in the body with a minimal clearance between an outside diameter of the tubular end portions and an inside diameter of the receptacles;
each collar, each skirt, each valve seat and each tubular end portion defining a respective dampening chamber proximate each adapter that receives fluid as the shuttle moves away from the adapter, the minimal gap restricting the flow of fluid into each dampening chamber from the outlet and the minimal clearance restricting the flow of fluid into each dampening chamber from the inlet;
whereby each shuttle is less susceptible to disruption from momentary pressure changes from the sources of pressurized fluid.

[c20] The apparatus of claim 19 wherein each shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c21] The apparatus of claim 19 wherein the amount of time it takes each shuttle to move from sealing engagement

with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c22] The apparatus of claim 19 wherein the amount of time it takes each shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c23] The apparatus of claim 19 wherein each shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 second or shorter.

[c24] The apparatus of claim 19 wherein the minimal gap and the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c25] The apparatus of claim 19 wherein the ratio of the minimal gap to the diameter of the central collar of each elongate shuttle is about 0.05% to about 0.2%.

[c26] A retrofit kit for an existing stacked shuttle valve to convert the valve to a chatter resistant design, the existing

stacked shuttle valve directing fluid flow from three or more sources of pressurized fluid to a downstream apparatus, the existing shuttle valve having a body with a plurality of adapter ports and a transverse outlet in fluid communication with the downstream apparatus, the retrofit kit comprising:

c) a plurality of removable adapters each engaging the adapter ports in the valve body, each adapter defining an inlet in fluid communication with a source of pressurized fluid;

a metal valve seat surrounding an inlet in each adapter;

a skirt extending from the adapter and surrounding each metal valve seat in each adapter;

d) a plurality of shuttles coaxial with the inlet and slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in the body in response to differential fluid flow from the sources of pressurized fluid;

each shuttle including a central collar with opposing metal sealing surfaces to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a circular band formed on an outside diameter, the circular band being sized to alter-

nately slip inside the first skirt with a minimal gap between the outside diameter of the collar and an inside diameter of the skirt;

the first tubular end portion being sized to slip inside a bore in the first adapter with a minimal clearance between the outside diameter of the first end portion and the inside diameter of the bore of the first adapter;

the second tubular end portion being sized to slip inside a bore in the second adapter with a minimal space between the outside diameter of the second end portion and the inside diameter of the bore of the second adapter; and

each central collar, each skirt, each valve seat in the adapter, and each tubular end portion proximate the adapter, defining a dampening chamber that resists short duration intervals of low pressure fluid in the outlet and the inlets and retards movement of the shuttle from a closed position at the inlet.

[c27] A chatter resistant shuttle valve to direct fluid flow from at least two sources of pressurized fluid to a downstream apparatus, the shuttle valve comprising:

a body engaging a pair of removable opposing coaxial adapters, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid and

the body having a transverse outlet in fluid communication with the downstream apparatus;

a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the body;

a first lip extending from the body and surrounding the first metal valve seat and a second lip extending from the body and surrounding the second metal valve seat;

an elongate shuttle coaxial with the inlets slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to fluid flow from the sources of pressurized fluid;

the shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and a second opposing sealing surface to engage the second valve seat, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a band formed on an outside diameter, the band being sized to alternately slip inside the first lip and the second lip with a minimal gap between the outside diameter of the collar and an inside diameter of the lips;

the first and second tubular end portions of the shuttle sized to alternatively slip inside a first receptacle in the first adapter and a second receptacle in the second adapter with a minimal clearance between an outside diameter of the tubular end portions and an inside diameter of the receptacles;

the collar, the first lip, the first valve seat and the first tubular end portion defining a first dampening chamber that receives fluid as the shuttle moves away from the first adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the first tubular end portion and the inside diameter of the receptacle restricting the flow of fluid into the first dampening chamber from the inlet; and

the collar, the second lip, the second valve seat and the second tubular end portion defining a second dampening chamber that receives fluid as the shuttle moves away from the second adapter, the minimal gap restricting the flow of fluid into the dampening chamber from the outlet and the minimal clearance between the outside diameter of the second tubular end portion and the inside diameter of the second receptacle restricting the flow of the fluid into the second dampening chamber from the inlet whereby the shuttle is less susceptible to disruption from momentary pressure changes from the

sources of pressurized fluid.

[c28] The apparatus of claim 27 wherein the shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c29] The apparatus of claim 27 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c30] The apparatus of claim 27 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c31] The apparatus of claim 27 wherein the shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 second or shorter.

[c32] The apparatus of claim 27 wherein the minimal gap and

the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c33] The apparatus of claim 27 wherein the ratio of the minimal gap to the diameter of the central collar of the elongate shuttle is about 0.05% to about 0.2%.

[c34] A retrofit kit for an existing shuttle valve to convert the valve to a chatter resistant design, the existing shuttle valve directing fluid flow from two or more sources of pressurized fluid to a downstream apparatus, the existing shuttle valve having a body with two opposing adapter ports and a transverse outlet in fluid communication with the downstream apparatus, the existing shuttle valve further including a pair of removable opposing coaxial adapters each engaging the adapter ports in the valve body, the first adapter defining a first inlet and the second adapter defining a second inlet, each inlet in fluid communication with a source of pressurized fluid, the adapters further defining a first metal valve seat surrounding the first inlet and a second metal valve seat surrounding the second inlet, the metal valve seats being coaxially aligned on opposite sides of the valve body, the valve body further defining a first lip extending from the body and surrounding the first metal valve seat and a second lip extending from the body and surround-

ing the second metal valve seat, the retrofit kit comprising:

an elongate shuttle coaxial with the inlets and slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in response to differential fluid flow from the sources of pressurized fluid;

the shuttle including an enlarged central collar with opposing metal sealing surfaces to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a circular band formed on an outside diameter, the circular band being sized to alternately slip inside the first lip and the second lip with a minimal gap between the outside diameter of the collar and an inside diameter of the lips;

the first tubular end portion being sized to slip inside a bore in the first adapter with a minimal clearance between the outside diameter of the first end portion and the inside diameter of the bore of the first adapter;

the second tubular end portion being sized to slip inside a bore in the second adapter with a minimal clearance between the outside diameter of the second end portion and the inside diameter of the bore of the second

adapter;

the central collar, the first lip, the first valve seat, and the first tubular end portion defining a first dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and the second inlet and retards movement of the shuttle from a closed position at the first inlet; and

the central collar, the second lip, the second valve seat, and the second tubular end portion defining a second dampening chamber that resists short duration intervals of low pressure from fluid in the outlet and the first inlet and retards movement of the shuttle from a closed position at the second inlet.

[c35] The apparatus of claim 34 wherein fluid flows a) from the outlet and the second inlet into the first dampening chamber through an annular area between the first lip and the shuttle central collar and fluid flows b) from the first inlet into the first dampening chamber through an annular area between the first tubular end portion of the shuttle and the bore of the first adapter.

[c36] The apparatus of claim 34 wherein the shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c37] The apparatus of claim 34 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c38] The apparatus of claim 34 wherein the amount of time it takes the shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c39] The apparatus of claim 34 wherein the shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 second or shorter.

[c40] The apparatus of claim 34 wherein the minimal gap and the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c41] The apparatus of claim 34 wherein the ratio of the minimal gap to the diameter of the central collar of the elongate shuttle is about 0.05% to about 0.2%.

[c42] A stacked chatter resistant shuttle valve to direct fluid flow from at least three sources of pressurized fluid to a downstream apparatus, the stacked shuttle valve comprising:

a segmented body having a first supply port and a plurality of adapters defining subsequent supply ports and a function port, each supply port in fluid communication with one source of pressurized fluid, and the function port in fluid communication with the downstream apparatus;

a zigzag shaped fluid passageway in the body connecting the supply ports and the function port allowing fluid to move from the sources of pressurized fluid, through the supply ports, through the fluid passageway, through the function port to the downstream apparatus;

each adapter having a first metal valve seat surrounding the supply port:

the segmented body defining opposing metal valve seats coaxial with each adapter, each opposing valve seat surrounding a portion of the passageway;

each body segment further defining a lip surrounding each opposing coaxial metal valve seat;

each of the subsequent supply ports having a shuttle coaxial with the metal valve seats, slidably moving from sealing engagement with the first valve seat to sealing

engagement with the opposing valve seat in response to fluid flow from the sources of pressurized fluid

each shuttle including a central collar with opposing metal sealing surfaces to engage the first valve seat and the opposing valve seat, each shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

each central collar having a band formed on an outside diameter, the band being sized to slip inside the lip with a minimal gap between the outside diameter of each collar and an inside diameter of each lip;

the first and second tubular end portions of each shuttle sized to alternatively slip inside a first receptacle in each adapter and a second receptacle in the body with a minimal clearance between an outside diameter of the tubular end portions and an inside diameter of the receptacles; and

each collar, each lip, each opposing coaxial metal valve seat surrounding a section of the passageway and a tubular end portion defining a respective dampening chamber opposite each adapter that receives fluid as the shuttle moves away from the body, the minimal gap restricting the flow of fluid into each dampening chamber from the outlet and the minimal clearance restricting the flow of fluid into each dampening chamber from the in-

lets; whereby each shuttle is less susceptible to disruption from momentary pressure changes from the sources of pressurized fluid.

[c43] The apparatus of claim 42 wherein each shuttle will oscillate from sealing engagement with one valve seat to sealing engagement with the opposing valve seat five times or less in response to full differential pressure from the sources of pressurized fluid.

[c44] The apparatus of claim 42 wherein the amount of time it takes each shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is in the range of about 1/8 to 1/12 second.

[c45] The apparatus of claim 42 wherein the amount of time it takes each shuttle to move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat under full differential pressure from the sources of pressurized fluid is about 1/10 second.

[c46] The apparatus of claim 42 wherein each shuttle does not move from sealing engagement with one valve seat to sealing engagement with the opposing valve seat in respond to pressure spikes having a duration of 1/13 sec-

ond or shorter.

[c47] The apparatus of claim 42 wherein the minimal gap and the minimal clearance are between 0.0005 and 0.002 inches for a valve having nominal inlets of 1 inch diameter.

[c48] The apparatus of claim 42 wherein the ratio of the minimal gap to the diameter of the central collar of each elongate shuttle is about 0.05% to about 0.2%.

[c49] A retrofit kit for an existing stacked shuttle valve to convert the valve to a chatter resistant design, the existing stacked shuttle valve directing fluid flow from three or more sources of pressurized fluid through a transverse outlet to a downstream apparatus, the stacked shuttle valve further including a plurality of removable segmented body portions each receiving an adapter, each adapter defining an inlet in fluid communication with a source of pressurized fluid, each segmented body portion having a metal valve seat opposing each adapter and a lip surrounding each metal valve seat, the retrofit kit comprising:
a plurality of shuttles coaxial with the inlets and slidably moving from sealing engagement with the first valve seat to sealing engagement with the second valve seat in the body in response to differential fluid flow from the

sources of pressurized fluid;

each shuttle including an enlarged central collar with opposing metal sealing surfaces to engage the valve seats, the shuttle further including opposing first and second tubular end portions, each with an axial bore and a plurality of perforations through the tubular end portion to the bore;

the central collar having a circular band formed on an outside diameter, the circular band being sized to slip inside the lip with a minimal gap between the outside diameter of the collar and an inside diameter of the lip;

the tubular end portion being sized to slip inside a bore in the segmented body portion with a minimal clearance between the outside diameter of the first end portion and the inside diameter of the bore in each segmented body portion; and

each central collar, each lip, each valve seat in each segmented body portion, and each tubular end portion opposite the adapter, defining a dampening chamber that resists short duration intervals of low pressure fluid in the outlet and the inlets that retards movement of the shuttle away from the body.

[c50] A chatter resistant shuttle valve to direct fluid flow from at least two sources of pressurized fluid to a downstream apparatus, the shuttle valve comprising:

a body having first and second inlets and an outlet in flow communication with one another;
a pair of valve seats positioned within said body, each valve seat surrounding a respective said first or second inlet;
a shuttle moveably mounted within said body and having a pair of opposed valve seat engaging surfaces adapted to selectively engage a respective valve seat, said shuttle having a radially projecting collar generally centrally along the length of the shuttle with the valve seat engaging surfaces on opposite sides of the collar, said shuttle having a pair of tubular members, each tubular member extending from an opposite side of the collar, said tubular members each having an outer surface and said collar having an outer surface, said tubular members each being received within a respective receptacle positioned within the valve body, each said receptacle having an inside surface mating to a respective tubular member outside surface;
at least one variable volume dampening chamber formed between a valve seat engaging surface on said collar and its respective valve seat the exterior of the respective tubular member and a surface partially defining an outer periphery of a pocket at a central end of a receptacle with the pocket having a diameter larger than the diameter of the respective receptacle, and

at least one bleed flow path communicating with the dampening chamber for receiving fluid within the valve therein as the shuttle moves from a closed position wherein the dampening chamber has a substantially no volume toward an open position, said bleed flow passage to the dampening chamber being such that the shuttle has a controlled rate of opening movement from the valve seat.

[c51] A chatter resistant shuttle valve as set forth in claim 50 wherein there is a said dampening chamber on each side of said collar.

[c52] A chatter resistant shuttle valve as set forth in claim 50 wherein the bleed flow passage has increasing size from the respective valve seat to its respective valve open position.